PATENT SPECIFICATION

619,107

Application Date: Nov. 21, 1946. No. 34479/46.

Complete Specification Left: Sept. 26, 1947.

Complete Specification Accepted: March 3, 1949.

Index at acceptance:—Classes **82(i)**, A(1d: 2a), A8(a: k: m: r: v: z12); **83(ii)**, A166; **83(iv)**, E10a3, S4; **and 110(iii)**, B2b(2: 3).

PROVISIONAL SPECIFICATION

Improvements in and relating to Turbine Blading

We, THE BRUSH ELECTRICAL ENGINEERING COMPANY LIMITED, a British Company, of Nottingham Road, Loughborough, Leicestershire, and JAMES WORLLEDGE BANKS, a British Subject, of 9, Idbury Road, Erdington, Birmingham, England, do hereby declare the nature of this invention to be as follows:—

This invention concerns turbine blading and rotors and stators incorporating such blading. It is primarily concerned with gas turbine blading but is also applicable to steam turbine blading. Its chief object is to improve the efficiency of gas turbine blading and to reduce the stresses in the turbine wheel by lightening the blades. In this last respect the invention has advantages when applied to steam turbine blading as well as to gas turbine blading.

It is well known that one of the factors limiting the efficiency of gas turbines is the restriction imposed upon the maximum gas temperatures that may be employed by the ability of the blading to withstand these temperatures. It will therefore be appreciated that if the blading can be adequately cooled higher gas temperatures can be employed, with increase in efficiency: alternatively, or in addition, inferior or more common materials can be employed in the construction of the blades. The said blades may be cooled by making them of hollow construction and by passing a stream of a cooling medium (specifically, air) through them. The use of hollow blades has the advantage of lightness but numerous manufacturing difficulties are encountered and a specific object of the present invention is a satisfactory method of manufacture of hollow turbine blades with integral cooling fins.

The invention provides a method for the production of a hollow turbine blade with integral fins or ribs at its interior, which consists in taking two components curved in cross section and one having fins at its convex face and the other having fins at its concave face and uniting said components at their longitudinal edges so that the first one forms the concave face and the second forms the convex face of the blade. The invention also provides a method for the production of turbine blading which comprises taking a plurality of substantially flat components each having a ribbed or finned face, pressing each of them to a concave shape in which the ribs are presented at the concavity of one component and at the convexity of the other by the employment of press tools including a readily deformable pressure member which is applied to the ribbed face, and uniting the components to form a hollow blade with the ribs presented at its interior. It will readily be appreciated that intricate and difficult manufacturing processes would be involved in the machining of ribs in the hollow interior of a one-piece blade and that difficulties would also be encountered in machining ribs on the face of a component which is curved in cross section. The process just defined, however, permits the ribs or fins to be formed (e.g. by milling or other machining, or by rolling) on the flat face of a plane component, the said component being thereafter bent to the required curvature. The use of a readily deformable pressure member is an important factor in the bending process, since it will be appreciated that were the flat component pressed between two rigid die members the ribs or fins would be liable to be crushed. The fact that the die member is deformable obviates this difficulty, the material for the said member being so chosen that while it affords an adequate support it readily permits the fins to change their spacing as the component is bent without causing the fins to be crushed or distorted. Rubber, and pitch, have been found to be eminently suitable materials.

The hollow blade thus formed is desirably located on a central core with the

inner tips of the ribs or fins making contact with the surface of the core. It is further preferred that the said fins shall be united to the core by a process analagous to soldering or brazing in that it involves the use of molten joining metal. Thus, between the core and the outer shell of the blade there is a cavity which is subdivided by the fins into a multiplicity of small conduits extending lengthwise of the blade. The surface area of these conduits is very substantial and since if air or other cooling medium is passed along said conduits this large area is exposed to the flow an effiecient cooling of the blade results. It will further be appreciated that due to the cavity the blade is substantially lighter than would be a normal solid blade of the same cross sectional area, while on the other hand the blade is extremely strong and rigid.

The foregoing and other features of the invention are incorporated in the method of manufacture and the product that will now be described as an example.

In the preferred method of manufacture the desired cooling fins or ribs are milled in one face of a flat metal plate. Conveniently, they are $^{1}/_{32}''$ wide and $^{1}/_{16}''$ deep and the slots between them are $^{1}/_{32}''$ wide. The metal employed may be that sold under the Registered Trade Mark Nimonic 80, or Nimonic 75 or may be a stainless steel such for example as that known as FDP stainless steel (i.e. Firth's Disintregation-Proof). Inferior grades of steel or other metal, can, however be used owing to the good cooling of the blades constructed in the manner herein described: It is contemplated that mild steel may be used in both gas and steam turbines.

The plate thus machined is then cut into two narrow plates, one somewhat wider than the other, along a line parallel with the fins. The wide plate is then placed in a die whereof the female member is of metal and the male member is a suitably shaped block of rubber. Pressure is exerted by this rubber block against the rib or fins of the plate and the latter is therefore bent within the metal die into a deep trough which has the ribs extending along its concave face. Since the rubber die is capable of yielding it conforms to the irregular surface of the extremities of the ribs and causes the plate to assume the shape of the interior of the female die without deforming the ribs or crushing them and in the resultant trough, which is substantially **V**-shaped with a radius at the bottom, the ribs are substantial normal to the flanks and radial to the curved base.

The narrower plate is placed with its ribbed face downwards on a block of pitch or rubber, and to its plain face a metal die is applied having its operative surface slightly convex. As the plate is pressed into the pitch or rubber its plain upper face is given a concave configuration: in this instance, also the shaping of the plate is achieved without crushing or deforming the ribs, the latter being disposed substantially radially on the convex face of the resultant component.

These two shaped components are then assembled so that the second mentioned plate closes the mouth of the trough of the first plate, the ribs on both plates being presented to the hollow interior. The plates are then welded together along their edges, at locations which constitute the leading and trailing edges of the eventual blade. The exterior of the blade is now rough ground to size and it is placed in a jig and a sizing broach is passed through the centre. Thereby the extremities of the ribs are machined so that the interior of the blade is of the requisite size and shape. After this the exterior of the blade is ground to its finished dimensions.

It is necessary to fit a number of such blades to a turbine disc. The disc is machined from austenitic steel, for example a stainless steel containing 18% chromium, a suitable steel being that sold under the Registered Trade Mark "Stayblade". The periphery of the disc is gashed across and a series of radial posts is milled out of it. Each post has the same shape as the hollow interior of the blade but is slightly larger in its sectional dimensions so as to give an intereference fit. A blade is then pressed endwise onto each post so that the inner extremities of the ribs fit tightly against the periphery of the post. The post may be of uniform size throughout its length or it may be tapered. In either instance it may be hollow.

Short wires of a soldering metal are then placed one between each of successive fins. The wheel is placed in a mould made of carbon or fire clay (which is shaped so as adequately to support the wheel and to avoid distortion of the latter) and is put in a furnace wherein it is raised to such a temperature that the metal of the wires runs and the tips of the fins are soldered to the posts and the shell of the blade is soldered to the rim of the wheel. After being permitted to cool the wheel is heat treated at a temperature (e.g. in the region of 750° to 800°C.) which is lower than the melting point of the "solder" in order to raise the strength of the soldered joint and disc material.

Various metals or alloys having a melt-

ing point lower than that of the material of the blade and the wheel, and higher than the temperature reached by the blades in use, may be employed for soldering. One alloy contains 50% nickel, 8% tin, 3% silicon, the balance being copper. Another alloy contains 5% nickel, 5% iron, and 5% aluminium, the balance being copper. Another suitable alloy is that employed in the welding process known by the Registered Trade Mark " Sifbronze ".

After the heat treatment the wheel is finally machined so as to eliminate any distortion that may have taken place.

In this condition it will be seen that, looking on the exposed outer end of the blade, the latter contains a great number of separate box-section compartments or conduits extending for its full length. It is intended that a cooling medium primarily air, shall be constrained to flow through these conduits. This medium may flow outwards through all conduits or it may flow outwards through some of them and then inwards through the others. For this latter purpose the end of the blade is blanked off by an appropriate cap, welded, brazed, soldered or riveted in position. Preferably, the fins are machined away for a short distance below the outer edge of the blade shell, which latter is level with the end of the post. On the end of the post there is a protruding stub which forms a rivet. An end plate or cap with a suitable hole is placed over this rivet and the latter riveted over: subsequently the edges of the cap are welded, brazed or soldered to the shell. This last mentioned operation may be carried out at any suitable stage in the fabricating process, preferably while the blade is being " soldered " to its post. In this manner there is formed a channel which extends all round the post at the outer end of the blade and the small conduits between the fins communicate with it. Thus, air or other fluids may be forced up these conduits which lie to one side of the central plane of the wheel and, entering the channel, flows along the latter and down the outer conduits at the other side of said plane.

The air flow may be provided by a fan or impellor formed on or attached to one face of the wheel and the rim of the wheel may be suitably pierced to expose the inner ends of the blade conduits. In order that the inner ends of all those conduits that lie on one and the same side of the central plane of the wheel shall be in communication, the fins may be machined back at the inner end of the blade to form a channel like that at the outer end of the blade except in that it may be desirable to divide this channel substantially at said plane by leaving one rib on each component of the blade at its full length.

The rim of the disc may be recessed around the root of each post to form a socket in which the inner end of the blade fits and is brazed or soldered. The said rim may be wider than the central area of the wheel and said recess may extend through the rim at each face of said central area. Thereby the desired communication with the inner ends of the blade conduits is produced. Alternatively said wide rim may be built up of a circular series of arcuate members each having one end convex to fit the concavity at one face of a blade and the other end concave to fit the convexity of the opposite face of the next blade, said members being brazed or soldered to the blades.

It will be appreciated that by passing a cooling medium (either liquid, gaseous, or both) through the blades manufactured as herein described it is possible to keep the outer shell of the blades and the blade posts at a temperature well below that at which accelerated creep commences, even when gas temperatures are used which are much-higher than those at present in use in industrial or aircraft gas turbines (e.g. above 800°C.). The posts will be maintained at a temperature which is less than that of the shells of the blades. The posts therefore do not reach a temperature at which the ultimate tensile strength is greatly effected and since the centrifugal loads are taken by both the skin and posts of the blade it will be appreciated that much higher wheel speeds can be used than heretofore if it is so desired. The ultimate tensile strength being practically unaffected and the creep rate very low the life of the blade is materially increased, and because higher gas temperatures can be used the efficiency of the turbine will be improved. Furthermore, the lightness of the hollow blades leads to reduced centrifugal loads and permits of higher rotational speeds being employed if so desired.

It may be pointed out that while the invention is primarily applicable to turbine wheels or rotors, it is also applicable to turbine stators.

In a modification, the shell of the blade is tapered in thickness from the root towards the tip. This taper is produced by machining the exterior of the blade, either after fabrication or preferably before, by grinding the plane faces of the blade components. This operation may be carried out before the said components are pressed to shape, but is preferably carried out after.

Dated this 20th day of November, 1946.

ERIC POTTER & CLARKSON,
Chartered Patent Agents.

COMPLETE SPECIFICATION

Improvements in and relating to Turbine Blading

We, THE BRUSH ELECTRICAL ENGINEERING COMPANY LIMITED, of Nottingham Road, Loughborough, Leicestershire, England, a British Company, and JAMES WORLLEDGE BANKS, of 9, Idbury Road, Erdington, Birmingham, England, a British Subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention concerns turbine blading and rotors and stators incorporating such blading. It is primarily concerned with gas turbine blading but is also applicable to steam turbine blading. Its chief object is to improve the efficiency of gas turbines and to reduce the stresses in the turbine wheel by lightening the blades. In this last respect the invention has advantages when applied to steam turbine blading as well as to gas turbine blading.

It is well known that one of the factors limiting the efficiency of gas turbines is the restriction imposed upon the maximum gas temperatures that may be employed by the ability of the blading to withstand these temperatures. It will therefore be appreciated that if the blading can be adequately cooled higher gas temperatures can be employed, with increase in efficiency: alternatively, or in addition, inferior or more common materials can be employed in the construction of the blades. The said blades may be cooled by making them of hollow construction and by passing a stream of a cooling medium (specifically air) through them. The use of hollow blades has the advantage of lightness but numerous manufacturing difficulties are encountered and a specific object of the present invention is a satisfactory method of manufacture of hollow turbine blades with integral cooling fins.

The invention provides a method for the production of turbine blading which comprises taking a pair of substantially flat components each having a ribbed or finned face, pressing each of them to a concave shape in which the ribs are presented at the concavity of one component and at the convexity of the other by the employment of press tools including a readily deformable die member which is applied to the ribbed face, and uniting the components to form a hollow blade with the ribs presented at its interior. It will readily be appreciated that intricate and difficult manufacturing processes would be involved in the machining of ribs in the hollow interior of a one-piece blade and that difficulties would also be encountered in machining ribs on the face of a component which is curved in cross section. The process just defined, however, permits the ribs or fins to be formed (e.g. by milling or other machining, or by rolling) on the flat face of a plane component, the said component being thereafter bent to the required curvature. The use of a readily deformable die member is an important factor in the bending process, since it will be appreciated that were the flat component pressed between two rigid die members the ribs or fins would be liable to be crushed. The fact that the die member is deformable obviates this difficulty, the material for the said member being so chosen that while it affords an adequate support it readily permits the fins to change their spacing as the component is bent without causing the fins to be crushed or distorted. Rubber, and pitch, have been found to be eminently suitable materials.

The hollow blade thus formed is desirably located on a central core with the inner tips of the ribs or fins making contact with the surface of the core. It is further preferred that the said fins shall be united to the core by a process analagous to soldering or brazing in that it involves the use of molten joining metal. Thus, between the core and the outer shell of the blade there is a cavity which is subdivided by the fins into a multiplicity of small conduits extending lengthwise of the blade. The surface area of these conduits is very substantial and since if air or other cooling medium is passed along said conduits this large area is exposed to the flow and an efficient cooling of the blade results. It will further be appreciated that due to the cavity the blade is substantially lighter than would be a normal solid blade of the same cross sectional area, while on the other hand the blade is extremely strong and rigid.

The foregoing and other features of the invention are incorporated in the method of manufacture and the product that will now be described as an example and which is illustrated in the accompanying drawings in which:—

Figure 1 is a perspective view of a flat

ribbed metal plate before cutting into two component pieces;

Figure 2 is a perspective view of a die with the wider component in position before pressure is applied;

Figure 3 is a perspective view of the die and component during pressing;

Figure 4 is a perspective view of the component after pressing;

Figure 5 is a perspective view of the narrower component in position in the die before pressing;

Figure 6 is a perspective view of the component shown in Figure 5 after pressing;

Figure 7 is a perspective view of the two components in position to form a hollow blade;

Figure 8 is a longitudinal section through the blade with a jig and broach shown in chain dotted lines;

Figure 9 is a perspective view partly in section, showing the manner of fixing a blade to the disc;

Figure 10 is a sectional view showing the end of the blade blanked off by a cap;

Figure 11 is a cross-section of a blade showing the air conduits;

Figure 12 is a fragmentary view, partly in section, through a bladed disc;

Figure 13 is a sectional fragmentary view of a turbine wheel with attached hollow blades.

In the preferred method of manufacture the desired cooling fins or ribs 1 are milled in one face of a flat metal plate 2*x*. The fins and slots may be of any convenient size but preferably neither the thickness of the fin nor the width of the slot should be greater than $^1/_{20}$ of the width of the blade (i.e. the distance between the leading and trailing edges) and the total surface area of the finned side of the blade should not be less than twice the area of the unfinned side. In one specific example the said fins are $^1/_{32}$" wide and $^1/_{16}$" deep and the slots 3 between them are $^1/_{32}$" wide. The metal employed may be that sold under the Registered Trade Mark Nimonic 80 or Nimonic 75 or may be a stainless steel such, for example, as that known as F.D.P. stainless steel (i.e. Firth's Disentegration-Proof). Inferior grades of steel or other metal, can however be used owing to the good cooling of the blades constructed in the manner herein described. It is contemplated that mild steel may be used in both gas and steam turbines.

The plate thus machined is then cut into two narrow plates one somewhat wider than the other along a line parallel with the ribs 1. The wide plate 2 is then placed with its ribs uppermost in a die whereof the female member 4 is of metal and has a deep trough 6 and the male member 5 is a suitable shaped block of rubber. Pressure is exerted by this rubber block 5 agains the ribs 1 of the plate and the latter is therefore pressed into the trough 6 of the die member 4. Since the rubber die member 5 is capable of yielding it conforms to the irregular surface of the extremities of the ribs and causes the plate to assume the shape of the trough 6 without deforming the ribs 1 or crushing them and in the resultant trough which is substantially **V**-shaped with a radius at the bottom as shown in Figure 4, the ribs 1 are disposed on the inner concave face 7 of the plate substantially normal to the flanks and radial to the curved base.

The narrower plate 8 is placed with its ribbed face downwards on a block of pitch or rubber 9 and to its plain face a metal die member 10 is applied having its operative surface 11 slightly convex. As the plate 8 is pressed into the pitch or rubber 9 its plain upper surface is given a concave configuration; in this instance also the shaping of the plate 8 is achieved without crushing or deforming the ribs 1 the latter being disposed substantially radially on the convex face of the resultant component as shown in Figure 6.

These two shaped components are then assembled so that the said second mentioned plate 8 closes the mouth of the trough of the first plate 2 the ribs 1 of both plates being presented to the hollow interior as shown in Figure 7.

The plates 2 and 8 are then welded together along their edges at locations which constitute the leading and trailing edges of the eventual blade. The exterior of the blade is now rough ground to size and the blade placed in a jig 12 and a sizing broach 12*x* is passed through the centre. Thereby the extremities of the ribs 1 are machined so that the interior of the blade is of the requisite size and shape. After this the exterior of the blade is ground to its finished dimensions.

It is necessary to fit a number of such blades to a turbine disc 13. The disc 13 is machined from austenitic steel, for example a stainless steel containing 18% chromium a suitable steel being that registered under the Registered Trade Mark "Stayblade". The periphery of the disc 13 is gashed across and a series of radial posts 14 milled out of it (Figure 12). Each post 14 has the same shape as the hollow interior of the blade but is slightly larger in its sectional dimensions so as to give an interference fit. A blade is then pressed endwise on to each post 14 so that the inner extremities of the ribs 1 fit tightly against the periphery of

the post. The post may be of uniform size throughout its length or it may be tapered. In either instance it may be hollow.

Short wires of soldering metal are then placed between each of successive ribs. The wheel is placed in a mould made of carbon and fine clay (which is so placed as adequately to support the wheel and to avoid distortion of the latter) and is put in a furnace wherein it is raised to such a temperature that the metal of the wires runs and the tips of the fins 1 are soldered to the posts 14 and the shell of the blade is soldered to the rim of the wheel. After being permitted to cool the wheel is heat treated at a temperature (e.g. in the region of 750° to 800°C.) which is lower than the melting point of the "solder" in order to raise the strength of the soldered joint and disc material.

Various metals or alloys having a melting point lower than that of the material of the blade and the wheel, and higher than the temperature reached by the blades in use, may be employed for soldering. One alloy contains 50% nickel, 8% tin, 3% silicon, the balance being copper. Another alloy contains 5% nickel, 5% iron and 5% aluminium, the balance being copper. Another suitable alloy is that employed in the welding process known by the Registered Trade Mark Sif-bronze.

After the heat treatment the wheel is finally machined so as to eliminate any distortion that may have taken place.

In this condition it will be seen that looking on the exposed outer end of a blade (Figure 12) the latter contains a great number of separate box-section compartments or conduits 16 extending for its full length. It is intended that a cooling medium, primarily air, shall be constrained to flow outwards through some of them and then inwards through the others. For this latter purpose the end of the blade is blanked by an appropriate cap, welded, brazed, soldered or riveted in position.

Preferably the ribs 1 are machined away for a short distance below the outer edge of the blade which latter is level with the end of the post as shown at 17 Figure 10. On the end of the post 14 there is a protruding stud 18 which forms a rivet. An end plate or cap 19 with a suitable hole is placed over the rivet 18 and the latter is riveted over; subsequently the edges of the cap are welded, brazed or soldered to the shell. This last mentioned operation may be carried out at any suitable stage in the fabricating process. In this manner there is formed a channel 20 which extends all round the post 14 at the outer end of the blade and the small conduits 16 between the ribs communicate with it. Thus air or other fluids may be forced up these conduits which lie to one side of the central plane of the wheel and, entering the channel 20, flows along the latter and down the outer conduits at the other side of said plane.

The air flow may be provided by a fan or impeller 21 formed on or attached to one or each face of the wheel and the rim 22 of the wheel may be suitably pierced to expose the inner ends of the blade conduits 16. In order that the inner ends of all these conduits that lie on one and the same side of the central plane of the wheel shall be in communication; the ribs may be machined back at the inner end of the blade to form a channel like that at the outer end of the blade except in that it may be desirable to divide this channel substantially at said plane by leaving one rib of each component of the blade at its full length.

The rim 22 of the wheel may be recessed around the root of each post 14 to form a socket into which the inner end of the blade fits and is brazed or soldered. The rim 22 may be wider than the central web of the wheel and said recess may extend through the rim at each face of said web.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A method for the production of turbine blading which comprises taking a pair of substantially flat components each having a ribbed or finned face, pressing each of them to a concave shape in which the ribs are presented at the concavity of one component and at the convexity of the other by the employment of press tools including a readily deformable die member which is applied to the ribbed face, and uniting the components to form a hollow blade with the ribs presented at its interior.

2. A method for the production of a turbine blade which comprises taking a flat metal plate, machining cooling fins or ribs on one face thereof, cutting the metal plate into two narrow plates, one substantially wider than the other, along a line parallel with the fins, placing the wide plate in a die whereof the female member is of metal and the male member a block of rubber, exerting pressure on said rubber block against said fins or ribs of the plate thereby bending the latter into a deep trough which has the ribs extending along

its concave face; placing the said narrower plate with the ribbed face thereof downwards on a block of rubber, applying the convex operative face of a metal die to the plain face of said plate whereby the said face is given a convex configuration, and uniting the two plates to form a hollow blade with the ribs presented at its interior.

3. A turbine blade produced by either of the methods according to Claims 1 and 2.

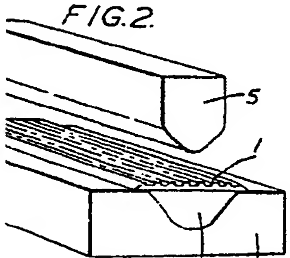
4. A turbine having blades according to the last preceding claim.

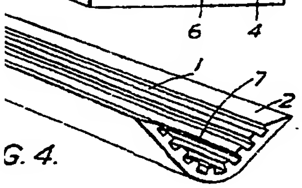
5. A method for the production of turbine blades, or a turbine blade produced by such a method, or a turbine having such blades, substantially as described and illustrated with reference to the accompanying drawings.

Dated this 25th day of September, 1947.
ERIC POTTER & CLARKSON,
Chartered Patent Agents.

Leamington Spa: Printed for His Majesty's Stationery Office by the Courier Press.—1949.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies, price 2s. 0d. each (inland) 2s. 1d. (abroad) may be obtained.

FIG.2.





G. 4.

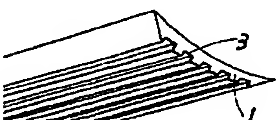
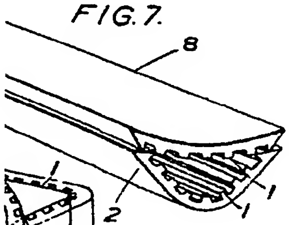


FIG. 6.

FIG.7.



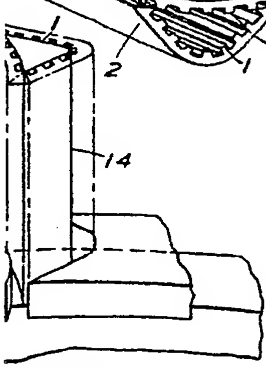


FIG.9.

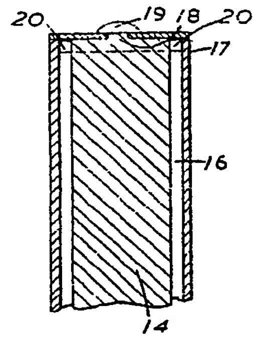


FIG. 10.

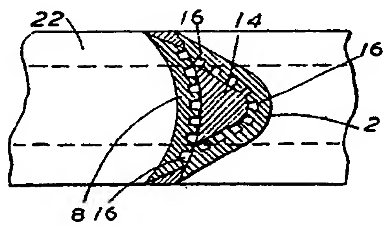


FIG. 11.

FIG. 12.

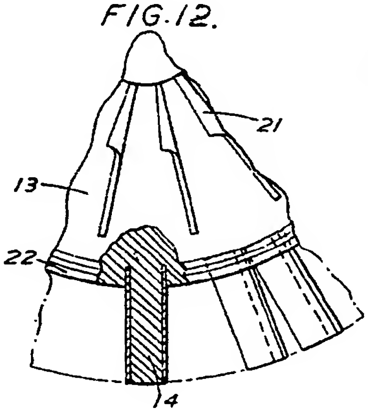
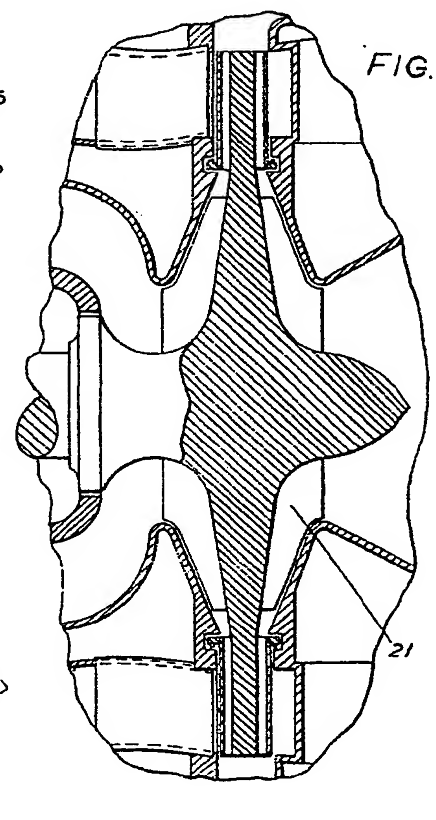


FIG. 13.



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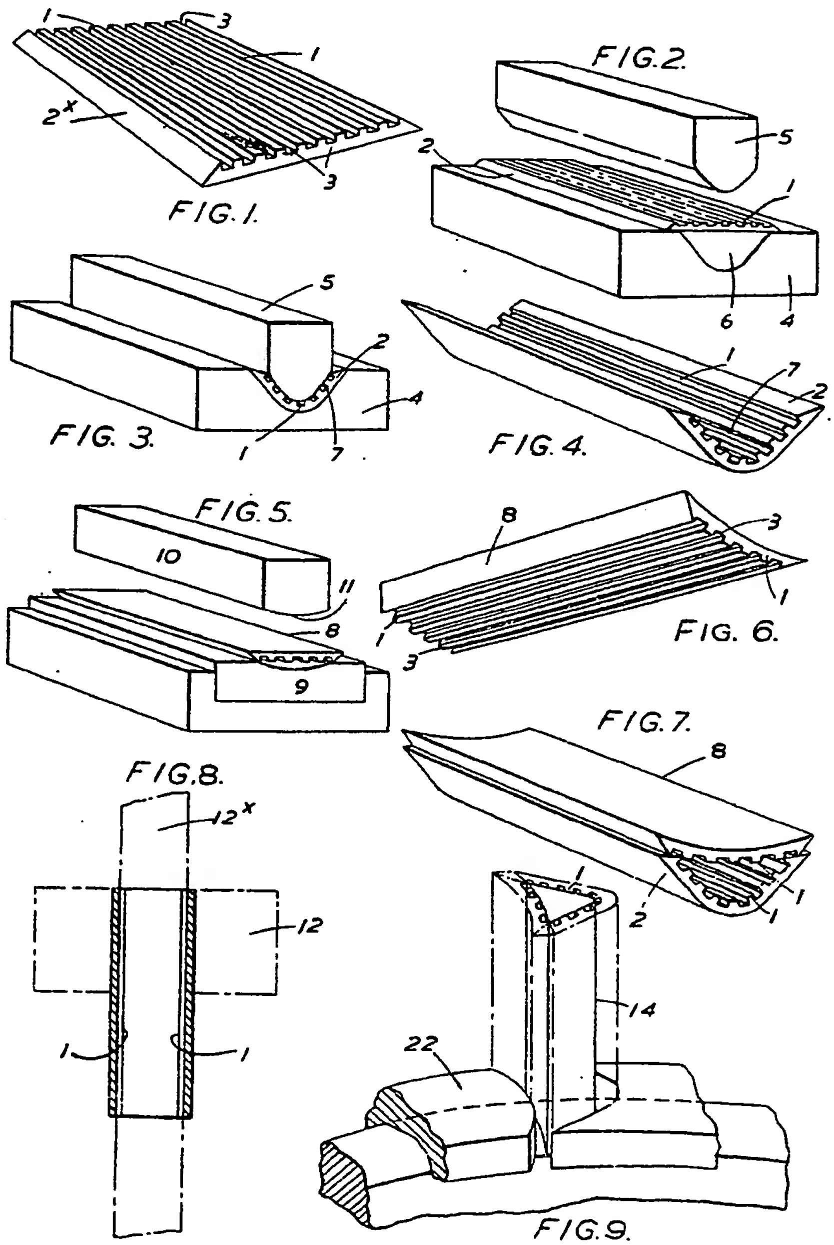

FIG. 1. FIG. 2. FIG. 3. FIG. 4. FIG. 5. FIG. 6. FIG. 7. FIG. 8. FIG. 9.

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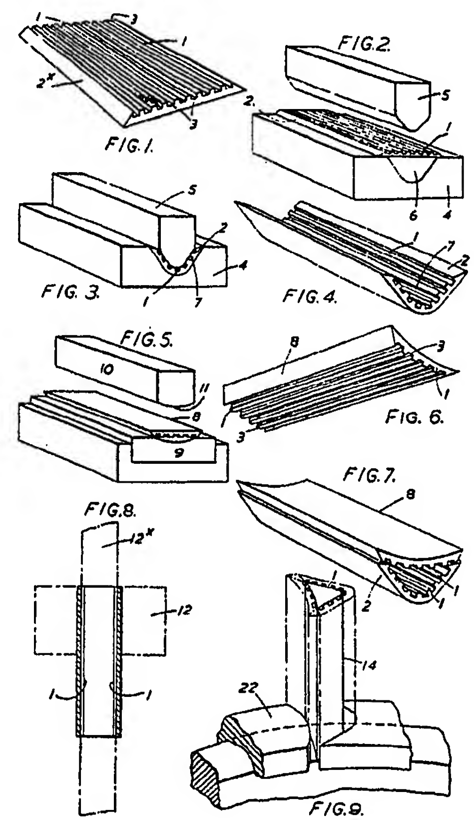

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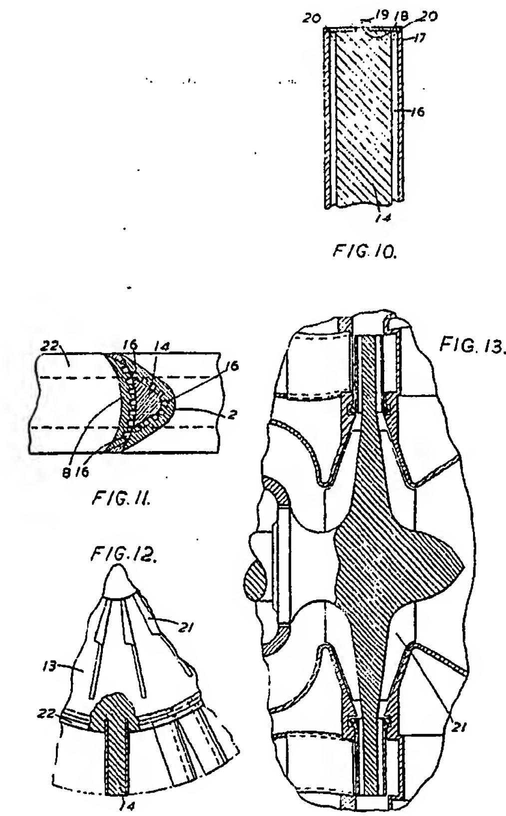

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